PHASE I INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM

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BOX ELDER CREEK DAM
PLENTYWOOD, MONTANA
SHERIDAN COUNTY
MT-934

PREPARED FOR:

HONORABLE TED SCHWINDEN
GOVERNOR, STATE OF MONTANA

CITY OF PLENTYWOOD
(OWNER AND OPERATOR)

PREPARED BY:
CH2M HILL
BELLEVUE, WASHINGTON
DECEMBER 1980

SEATTLE DISTRICT
UNITED STATES
ARMY CORPS OF ENGINEERS

DATE	ISSUED TO
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EXECUTIVE SUMMARY

Under contract with the Seattle District Corps of Engineers, and with representation from the Corps, the Montana Department of National Resources and Conservation (MDNRC), the City of Plentywood, and the U.S. Soil Conservation Service, CH2M HILL inspected Box Elder Creek Dam on October 30, 1979, under the authority of Public Law 92-367. The dam is located on Box Elder Creek in Sheridan County, Montana. The damsite is about 0.3 miles north of the city of Plentywood, Montana.

This report was compiled from information obtained during onsite inspection, review of construction plans, and analysis of available hydrologic information. Findings were compared with engineering criteria that are currently accepted by most private and public agencies engaged in dam design, construction, and operation.

FINDINGS AND EVALUATION

Box Elder Creek Dam is owned and operated by the City of Plentywood, Montana. The primary purpose of the project is flood control. The dam provides flood protection to the city of Plentywood. The reservoir is also used for recreation and storage of a small volume of irrigation water.

The 60-foot-high earth dam impounds approximately 6,620 acre-feet of water at top of dam, elevation 2121.1 feet National Geodetic Vertical Datum (NGVD). Elevations are based on levels taken during the inspection and using elevation 2090.5 as the crest of the principal spillway. On the basis of criteria in the U.S. Army Corps of Engineers Recommended Guidelines for Safety Inspection of Dams (Ref. 1), the project is intermediate in size. The dam is located such that its failure could cause flooding in the City of Plentywood and result in extensive damage and endanger many lives. However, no dam breach analysis or routing of a dam breach flood was made for the downstream area. The conclusions on probable damage are based on a brief field visit and engineering judgment.

The project is classified as having a high (Category 1) downstream hazard potential. Inspection criteria (Ref. 1) recommend that an intermediate-sized project with a high downstream hazard potential be capable of safely handling the probable maximum flood (PMF). The PMF is the flood expected from the most severe combination of meteorologic and hydrologic conditions that are reasonably possible in the region.

An estimated PMF was developed for the 20-square-mile drainage basin. The PMF resulting from the 72-hour general storm has an estimated volume of 20,800 acre-feet and a peak flow

of 66,600 cfs. The principal and emergency spillways have a combined maximum discharge capacity of 29,600 cfs with the reservoir at dam crest, elevation 2121.1 feet NGVD. The routing of the PMF was started with the reservoir level at the crest of the lower (west) emergency spillway, elevation 2113.6 feet NGVD to account for conditions that could be caused by antecedent floods.

Routing of the PMF and lesser floods indicates that the project can control a flood having hydrograph ordinates equal to approximately 49 percent of the PMF hydrograph ordinates.

A brief visual inspection of the dam embankment revealed neither longitudinal or transverse cracking nor any embankment or abutment contact seepage or erosion. The crest and slopes were adequately protected and uniform with no irregularities or slumps. The west and east emergency spillways are unlined and cut in highly erosive soils and could be expected to be severely damaged during flood discharges. The west emergency spillway discharges to the valley floor at the toe of the dam. Flood discharges would cause erosion of embankment materials which could lead to embankment failure. Stability analysis as well as supporting laboratory test information pertaining to both foundation and the embankment are on file. Based on a review of this information it is our judgment that the dam embankment stability conforms with the recommended guidelines. The embankment is constructed of materials that would quickly erode and rapidly fail when overtopped by floodwaters. Considerable damage could occur to the City of Plentywood prior to overtopping the dam embankment due to the large spillway capacity and the limited downstream channel capacity. However, a dam failure would endanger many lives and cause appreciable property damage. Because the project is incapable of controlling the PMF without overtopping and causing the dam to fail, Box Elder Creek Dam does not meet inspection guidelines with respect to safely handling the recommended spillway design flood.

The 30-inch-diameter discharge conduit for the principal spillway and low-level outlet could not be inspected during the site visit because of its small diameter. The principal spillway riser was not inspected because of lack of access ladders and safety equipment. No downstream warning system is in effect.

RECOMMENDATIONS

The intent of report recommendations is to improve project safety, while preserving the flood protection. A downstream warning system, for use in the event of possible dam overtopping or structural failure, needs to be developed and immediately placed in action. Inspect the principal spillway riser, the low-level outlet works, and the discharge conduit

and make any necessary repairs. The area at the bottom of the riser is subject to falling water and could be experiencing erosion; therefore, particular attention should be given to this area during the inspection. Conduct more detailed hydrologic and hydraulic routing studies to better determine the downstream hazard and required spillway capacity and modify the project as studies indicate. Study discharge characteristics of the emergency spillways and implement modifications to the west spillway channel to protect embankment from erosion during spillway discharges. Conduct periodic inspections of the project at no less than 5-year intervals by engineers experienced in dam design and construction. Prior to performing engineering studies and remedial work coordinate with the Montana DNRC to ensure compliance with all pertinent laws and regulations.

Richard L. Foster
Professional Engineer

PERTINENT DATA

1. General

Federal ID No.	MT-934
Owner/Operator	City of Plentywood
Date Constructed	1963
Purpose	Flood Control (with some recreation and irrigation)
Location	Section 17, T35N, R55E, Principal Meridian
County, State	Sheridan County, Montana
Watershed	Box Elder Creek
Downstream Hazard Potential	Category 1 (High)
USGS Quadrangle	Wolf Point, Montana; North Dakota
Size Classification	Intermediate

2. Reservoir

Surface Area at Principal Spillway Crest (Elevation 2090.5 feet NGVD)	100 acres
Drainage Area	20.0 square miles
Storage at Principal Spillway Crest (Elevation 2090.5 feet NGVD)	1,220 acre-feet
Storage at West Emergency Spillway Crest (Elevation 2113.6* feet NGVD)	4,940 acre-feet
Storage at East Emergency Spillway Crest (Elevation 2115.1* feet NGVD)	5,300 acre-feet
Storage at Dam Crest (Elevation 2121.1* feet NGVD)	6,620 acre-feet
Surcharge Storage (Principal Spillway to Crest of Dam)	5,400 acre-feet

Reservoir Pool Elevation on 10/30/79 (date of inspection)		2087.7 feet NGVD
3. Principal Spillway		
Type		Uncontrolled drop inlet
Conduit		30-inch-diameter concrete
Crest Elevation		2090.5 feet NGVD
Conduit Length		290 feet
Capacity with Reservoir at Dam Crest		150 c.f.s.

4. Emergency Spillways	West	East
Type	Uncontrolled, grass-lined channel	Uncontrolled, grass-lined channel
Bottom Width (Control Section)	410 feet	180 feet
Crest Elevation	2113.6* feet NGVD	2115.1* feet NGVD
Capacity with Reservoir at Dam Crest	23,500 c.f.s.	5950 c.f.s.

5. Outlet Works	
Conduit	12-inch-diameter steel, discharging to principal spillway riser
Conduit Length	80 feet
Gate	12-inch-diameter gate valve
Capacity with Reservoir at Principal Spillway Crest	15 c.f.s.
6. Dam	
Type	earthfill
Length	1,800 feet
Crest Width	18 feet
Crest Elevation	2121.1* feet NGVD

Hydraulic Height (Crest to Toe)	60 feet
Upstream Slope	1 V on 4 H 1 V on 3 H
Downstream Slope	1 V on 2.5 H

*Elevations are based on levels taken at time of inspection and using elevation 2090.5 feet NGVD as crest of principal spillway.

Chapter 1
BACKGROUND

1.1 INTRODUCTION

1.1.1 Authority and Scope

This report summarizes the Phase I inspection and evaluation of the Box Elder Creek Dam, owned by the City of Plentywood.

The National Dam Inspection Act, Public Law 92-367, dated August 8, 1972, authorized the Secretary of the Army, through the Corps of Engineers, to conduct safety inspections of non-Federal dams throughout the United States. Pursuant to that authority, the Chief of Engineers issued "Recommended Guidelines for Safety Inspection of Dams" in Appendix D, Volume 1 of the U.S. Army Corps of Engineers' report to the United States Congress on "National Program of Inspection of Dams" in May 1975.

The recommended guidelines were prepared with the help of engineers and scientists highly experienced in dam safety from many Federal and state agencies, professional engineering organizations, and private engineering consulting firms. Consequently, the evaluation criteria presented in the guidelines represent the comprehensive consensus of the engineering community.

Where necessary, the guidelines recommend a two-phased study procedure for investigation and evaluation of existing dam conditions, so deficiencies and hazardous conditions can be readily identified and corrected. The Phase I study is:

(1) a limited investigation to assess the general safety condition of the dam.

(2) based upon an evaluation of the available data and a visual inspection.

(3) performed to determine if any needed emergency measures and/or if additional studies, investigations, and analyses are necessary or warranted.

(4) not intended to include extensive explorations and analyses or to provide detailed alternative correction recommendations.

The Phase II investigation includes all additional studies necessary to evaluate the safety of the dam. Included in Phase II, as required, should be additional visual inspections, measurements, foundation exploration and testing, material testing, hydraulic and hydrologic analyses, and structural stability analyses.

The authority for the Corps of Engineers to participate in the inspection of non-federally owned dams is limited to Phase I investigations with the exception of situations of extreme emergency. In these cases, the Corps may proceed with Phase II studies but only to the extent needed to answer questions relating to dam safety that cannot be answered otherwise. The two phases of investigation outlined above are intended only to evaluate project safety and do not encompass in scope the engineering required to perform design or corrective modification work. Recommendations contained in this report may be for either Phase II safety analyses or detailed design study for corrective work.

The responsibility for implementation of these Phase I recommendations rests with the dam owner and the State of Montana. It should be noted that nothing contained in the National Dam Inspection Act, and no action or failure to act under this Act shall be construed (1) to create liability in the United States or its officers or employees for the recovery of damage caused by such action or failure to act or (2) to relieve an owner or operator of a dam of the legal duties, obligations, or liabilities incident to the ownership of the dam.

1.1.2 Purpose

The purpose of the inspection and evaluation is to identify conditions that threaten public safety, so that they may be corrected in a timely manner by non-Federal interests.

1.1.3 Inspection

The findings and recommendations in this report are based on a brief visual inspection of the project and a detailed review of available construction plans. Inspection procedures and criteria are those established by the Recommended Guidelines for Safety Inspection of Dams (Ref. 1).

Personnel present during the inspection included:

Richard Eckerlin, Geologist, Corps of Engineers
Art Taylor, State of Montana, Department of Natural Resources and Conservation
Chester Olson, City of Plentywood
Clifford Harchenko, U.S. Soil Conservation Service
August Abenroth, U.S. Soil Conservation Service

CH2M HILL personnel who participated in the field inspection and contributed to this report are:

Miles Bubenik, Geotechnical Engineer, Team Leader
Jerry Jacksha, Geotechnical Engineer
Loren Bottorff, Hydrologist/Hydraulics Engineer

This report has been reviewed by the City of Plentywood, the Montana DNRC and the U.S. Soil Conservation Service, and their written comments are enclosed at the end of the report.

1.2 DESCRIPTION OF PROJECT

1.2.1 General

Box Elder Creek Dam is located on Box Elder Creek, a tributary of Big Muddy Creek about 52 miles upstream of its confluence with the Missouri River. The damsite is approximately 0.3 miles north of Plentywood (Photo 1), in Sheridan County, Montana (see Plate 1). The dam provides flood protection for the city of Plentywood. The dam is listed as having a high (Category 1) downstream hazard potential. The Federal identification number is MT-934. The dam is 60 feet high and approximately 1,800 feet long and impounds 6,620 acre-feet at dam crest, elevation 2121.1 feet NGVD. The dam was constructed in 1963.

Based on visual reconnaissance and engineering judgment, a portion (probably over 100 homes) of the City of Plentywood could be affected by a sudden breach of the dam. On the basis of this information and in accordance with the recommended guidelines, the project size is intermediate, and the downstream hazard potential is high (Category 1).

The 100-acre reservoir is used primarily for flood control. Secondary uses include recreation and minor irrigation storage. The dam is owned and operated by the City of Plentywood, Montana.

The principal spillway is located near the center of the dam and consists of an uncontrolled drop inlet structure connected to a 30-inch-diameter reinforced concrete discharge conduit. There are two emergency spillways, one through each abutment (Plate 2). Each emergency spillway consists of an uncontrolled, grasslined excavated channel. The west emergency spillway channel is approximately 410 feet wide at the crest; the east channel is about 180 feet wide at the crest. The low-level outlet consists of a gated 12-inch-diameter steel conduit which discharges to the interior of the principal spillway riser.

1.2.2 Regional Geology and Seismicity

The regional geology and seismicity were addressed in a memorandum by R. D. Eckerlin (Ref. 2). The following information is taken from that memorandum.

> Box Elder Creek Dam lies on a portion of the Missouri Plateau that consists of a gently rolling till plain overlying the Paleocene Fort Union

Formation. In this region the Fort Union Formation is composed of thick interbedded gray to buff sandstone, clay shale, lignite, and carbonaceous shale. The regional dip of the formation is gentle to the east-southeast varying from 20 to 40 feet per mile. The area is capped with 30 to 50 feet of glacial till from the late Wisconsin ice sheet. The till is a gray, dense, calcareous clay, with some reworked Fort Union sediments and a variety of erratic pebbles, cobbles and boulders. Locally, terrace sands and gravels overlie the glacial till. The dam is situated where the valley is constricted by a terrace remnant that projects from the east valley wall. The abutments consist of smooth, relatively steep slopes separated by a wide flood plain. Box Elder Creek is located near the center of the flood plain.

The dam lies in an area of very low seismic activity. The closest historic seismicity was a magnitude 5.0 event, which occurred in 1943, 28 miles southwest of the dam. The Inspection Guidelines Seismic Zoning Map shows the site in Zone 1, a zone in which minor damage can be expected from earthquakes.

1.2.3 Site Geology

The site geology also was addressed in the R. D. Eckerlin memorandum (Ref. 2). The following information is based on parts of that memorandum.

Box Elder Creek Dam is constructed on alluvial flood-plain sediments. Preconstruction boreholes (Plate 3), drilled beneath the embankment, indicate the flood-plain sediments to be about 30 feet thick overlying clay shale bedrock. On the flood plain from the channel of Box Elder Creek to the west abutment, borings encountered lean to fat, slightly organic clay to a depth of approximately 30 feet. Below this depth, clay shale bedrock was encountered. Bedrock consists of stiff to hard, moist, moderately plastic clay shale. Borings in the flood plain from the channel of Box Elder Creek to the east abutment encountered a natural blanket of silty and sandy clay approximately 3 feet thick, underlain by moderately permeable sand, silty sand, silty gravel, and sandy gravel. Clay shale bedrock was encountered approximately 30 feet below the surface of elevation 2,035.7 feet.

Both abutments of the dam consist of glacial till, channel outwash, and terrace gravels. The east abutment consists of compact, nearly impervious glacial till. The bottom of the till was encountered in borings at elevation 2,072 feet. The till overlies stratified sediments consisting of fine silty sand and lean to fat clay. The west abutment consists of glacial till overlying clay shale bedrock. The east abutment appears to serve as a path for water seeping from the reservoir.

The principal spillway (outlet for the dam), concrete conduit beneath the embankment, is assumed to be founded on a 15- to 20-foot thickness of clay as discussed in the Watershed Work Plan (Ref. 3) and shown on Plate 3. The emergency spillways are excavated in the east and west abutments. The east spillway appears to be excavated and founded in glacial till, while the west spillway is excavated in glacial till with the spillway floor in clay shale bedrock. The till material on the east spillway floor is erodible when subjected to frequent or long duration flows.

The slopes exposed around the perimeter of the stilling basin consist of bedded silt and clay. The outlet ditch is excavated through silt and clay.

The reservoir is elongated in the north-south direction and lies within an alluvial valley cut through glacial till, outwash, and terrace gravel which overlie clay shale bedrock. The shoreline around the lake is basically glacial till that is composed of erratic pebbles in gray, dense, calcareous clay. Major landsliding along the reservoir does not appear to be a threat; however, there is wave erosion of the reservoir slopes.

1.2.4 Design and Construction History

The Box Elder Creek project, owned by the City of Plentywood, was designed and constructed in 1962 and 1963 by the U.S. Soil Conservation Service. As-built design analyses with supporting laboratory test data for both foundation and embankment materials, together with stability analysis, was available for our review.

In about 1975, the crest elevation of the principal spillway inlet structure was raised two feet to provide additional storage for irrigation use. Plates 2, 3, 4, 5, 6, 8, and 10 were developed from SCS construction drawings.

Chapter 2
INSPECTION AND RECORDS EVALUATION

2.1 HYDRAULICS AND STRUCTURES

2.1.1 Principal Spillway

The uncontrolled principal spillway and low-level outlet works at Box Elder Creek Dam discharge through a common conduit that passes through the embankment near the center of the dam (Plate 4). The uncontrolled principal spillway consists of a concrete drop inlet riser (Photo 2).

The riser (Plate 5) is about 23 feet high, with inside dimensions of 3'-6" x 3'-6". The top 3 feet of the riser are flared slightly to allow more flow area. A 9-inch-wide concrete splitter wall, at the centerline of the riser, extends 3.5 feet above the top of the riser and 0.75 feet below the top of the riser. The two sides of the riser that are parallel to the splitter wall slope away from the wall at 3 V on 1 H. In about 1975, the crest elevation of the principal spillway was raised 2 feet to provide additional storage for irrigation use. The riser was extended by adding 2 feet of steel plate around the perimeter, and a steel plate was added to the splitter wall. The crest elevation of the principal spillway is now at 2090.5 feet NGVD, which is 30.6 feet below the dam crest. A trashrack constructed of structural steel extends above the spillway riser.

The riser is connected to a 30-inch-diameter reinforced concrete discharge conduit which extends 290 feet through the dam. This conduit rests on a concrete cradle; from the boring logs, it appears the entire length is founded on about 30 feet of compressible material. It appears that the vertical riser conduit will not prevent a full-flow (pressurized) condition when the reservoir pool is approximately at an above elevation 2092 feet NGVD. Consequently it is possible that the conduit would be pressurized for several days while a flood event is being accommodated. This results in a pressurized conduit through the earthen embankment with no means for emergency closure at the upstream end. The conduit has a cantilevered outlet discharging to a riprapped stilling pool at the toe of the dam. The stilling pool discharges through an excavated grass-lined trapezoidal channel that re-enters the Box Elder Creek channel about 500 feet below the dam.

The discharge conduit was not inspected during the site visit because of its small size. The riser was not inspected because of the lack of access ladders and safety equipment.

The discharge rating for the principal spillway was computed by combining ratings for weir control at the riser crest, orifice control in the riser, and full pipe flow in the discharge conduit. The lip of the riser was assumed to operate as a sharp-crested weir with a discharge coefficient of 3.33. The discharge coefficient for orifice control was assumed to be 0.7. A Mannings "n" of 0.013 was used to compute friction losses for full flow conditions. The control was found to change from weir flow to full conduit flow when the reservoir level rises more than 1.5 feet above the top of the riser. The maximum principal spillway discharge with the reservoir level at the top of the dam, elevation 2121.1 feet NGVD, was estimated to be 150 c.f.s.

2.1.2 West Emergency Spillway

The west emergency spillway for Box Elder Creek Dam is excavated through highly erodible glacial till and weathered clay shale in the right abutment (Plate 6). The spillway is a grass-lined earth channel approximately 1,350 feet long. The control section consists of an earth weir, 50 feet in breadth, with a crest elevation of 2113.6 feet NGVD. This elevation is based on levels surveyed at the time of the site visit using known elevation 2090.5 feet NGVD (from as-built plans) for the crest of the principal spillway. The elevation of the weir is 0.6 of a foot higher than shown on the plans. The crest of the west emergency spillway is 7.5 feet below the low point on the dam, about 7 feet above the entrance to the spillway approach channel, and about 3 feet above the discharge channel.

The grass-lined spillway approach channel is about 450 feet long and has a width of about 410 feet (Photo 3). The channel has an adverse slope of .01 from the reservoir to the spillway crest. The approach channel makes a bend of 81° to the left (looking downstream) between the reservoir and the control section. The radius of curvature is 281 feet at the centerline of the channel.

The discharge channel is grass-lined and approximately 810 feet long. The channel width varies from about 400 feet just below the control section to about 260 feet at the lower end. The gradient is .0869 for about 550 feet downstream of the crest, reducing to .0125 at the outlet. The discharge channel makes a bend of 80.5° to the left (looking downstream) beginning at the control section. The radius of curvature is 281 feet at the centerline of the discharge channel. The west emergency spillway discharges to the valley floor at the toe of the dam without aid of an energy dissipation structure. The spillway is in very good condition but has never operated. The Box Elder Creek channel has inadequate capacity downstream of the dam to carry discharge from the emergency spillway. Structural damage could be

expected to occur to buildings along Box Elder Creek in Plentywood if the emergency spillway was operated. Operation of the west emergency spillway channel would also cause erosion of the dam embankment (see Plate 6.)

The discharge rating curve (Plate 7) for the west emergency spillway was developed by assuming that critical depth occurs at the control section and computing backwater effects in the approach channel between the spillway crest and the reservoir. A Mannings "n" of 0.03 was used. The maximum discharge capacity of the west emergency spillway with the reservoir at top of dam, elevation 2121.1 feet NGVD, is 23,500 c.f.s.

2.1.3 East Emergency Spillway

The east emergency spillway for Box Elder Creek Dam is excavated through the left abutment (Plate 8). The spillway consists of a grass-lined earth channel approximately 700 feet long. The control section consists of an earth weir, 60 feet in breadth, with a crest elevation of 2115.1 feet NGVD (Photo 4). This elevation is based on levels surveyed at the time of the site visit using known elevation 2090.5 feet NGVD (from as-built plans) for the crest of the principal spillway. The elevation of the weir is 1.1 feet higher than shown on the plans. The crest of the east emergency spillway is 6.0 feet below the low point on the dam, about 17 feet above the entrance to the spillway approach channel, and about 6 feet above the discharge channel.

The grass-lined spillway approach channel is about 400 feet long and has a width of about 180 feet. The channel has an adverse slope of .01 from the reservoir to the spillway crest.

The discharge channel is grass-lined and approximately 200 feet long. The channel width is about 180 feet. The channel is excavated with a variable gradient. The discharge channel makes a bend of 63° to the right (looking downstream) beginning at the control section. The radius of curvature is 322 feet.

The east emergency spillway has no energy dissipator and discharges to a natural gully that reenters the Box Elder Creek channel about 1,000 feet downstream from the toe of the dam. The spillway is in very good condition but has never operated. Several structures are located in the discharge channel (natural gully) and would be damaged or destroyed by spillway releases. The Box Elder Creek channel has inadequate capacity downstream of the dam to carry discharge from the emergency spillway. Additional structural damage would occur to buildings along Box Elder Creek in Plentywood if the emergency spillway operated.

The discharge rating curve (Plate 9) for the east emergency spillway was developed by assuming that critical depth occurs at the control section and by computing backwater effects in the approach channel between the reservoir and the spillway crest. A Manning's "n" of 0.03 was used. The maximum discharge capacity of the east emergency spillway with the reservoir at top of dam, elevation 2121.1 feet NGVD, is 5,950 c.f.s.

2.1.4 Outlet

The low-level outlet works consists of a 12-inch-diameter steel conduit and slide gate. The conduit discharges to the interior of the principal spillway riser (Plate 4). The conduit is 80 feet long from the intake structure to the riser and rests on about 30 feet of compressible material. The plans show the intake structure to consist of a concrete headwall fitted with a trashrack. The control gate is located in a small closed well alongside the riser. The gate operator is located on the upstream side of the principal spillway intake riser.

The discharge rating for the outlet works was developed with the gate fully open and assuming full conduit flow with Mannings "n" of 0.015. The maximum discharge with the reservoir at principal spillway crest, elevation 2090.5 feet NGVD, was estimated to be 15 c.f.s.

2.1.5 Freeboard

Flood routings (see paragraph 2.2.4) indicated that the dam overtops during the PMF, and, therefore, the dam has no freeboard with the recommended spillway design flood (SDF). The vertical distance between the low point on the dam and the reservoir level at the time of the October 30, 1979, inspection was 33.4 feet. The crest of the principal spillway is 30.6 feet below the low point on the dam crest; the crest of the west emergency spillway is 7.5 feet below the low point on the dam crest; and the crest of the east emergency spillway is 6.0 feet below the low point on the dam crest. The effective fetch for wind-generated waves on the reservoir is about one-half mile. Wave runup on the embankment is estimated to be less than 2.5 feet. Although the dam will overtop during the PMF, the vertical distance between the crest of the dam and the normal reservoir level is adequate to prevent overtopping the embankment by wind-generated waves. According to Mr. Abenroth of the U.S. Soil Conservation Service, the maximum reservoir level was about 4 feet above the top of the principal spillway riser; this would have left about 19 feet from reservoir level to west emergency spillway crest.

2.2 HYDROLOGY, CLIMATOLOGY, AND PHYSIOGRAPHY

2.2.1. General

The climate of the area is continental, characterized by warm summers, cold winters, and a semiarid precipitation regime. There is a climatological station at Plentywood, for which over 30 years of precipitation records are available. The nearest station where temperature data are collected is at Redstone, located about 18 miles west of the damsite. Mean annual precipitation at Plentywood is about 14.5 inches, with over 60 percent occurring from May through August. The mean annual temperature at Redstone (elevation 2110) is about 40 degrees Fahrenheit (°F) with monthly means ranging from a low of about 6°F in January to a high of about 69°F in July. Temperature extremes may range from -40°F to over 100°F. Precipitation on the Box Elder Creek Dam basin may average about the same as at Plentywood, and temperatures on the basin may average about the same as at Redstone.

The drainage area above Box Elder Creek Dam is 20 square miles in size. The basin is about 7.5 miles long and averages about 3 miles in width. Basin elevations range from 2090 feet NGVD at the dam to 2570 feet NGVD at the northern basin boundary. The basin is primarily grassland. The area is very sparsely populated. The basin is drained by Box Elder Creek, which enters the reservoir at the north end. There is no streamflow gage on Box Elder Creek or on any nearby streams.

Flooding in Plentywood has long been a problem. Box Elder Creek Dam was built specifically to alleviate this recurring problem. The U.S. Soil Conservation Service's "Watershed Work Plan" (Ref. 3) for Box Elder Creek mentions that over-bank flooding in Plentywood, before the dam was built, occurred with about the 2-year frequency storm, and serious flooding was caused from the 3- and 4-year frequency storms. The report summarizes some flooding damages:

> Plentywood experienced its most severe flood on June 30, 1953. Damage surveys, made by personnel of the Fort Peck District, Corps of Engineers, following this storm furnished valuable accounts of this and other damaging storms. During the June 30, 1953 flood two people lost their lives from drowning, and virtually all of a 20-block area was flooded to a maximum depth of about six feet. Four hundred people had to leave their homes, 100 homes were damaged, 77 basements filled with water and 31 homes had flooding above the first floor level. Five business places, streets, bridges and sewers sustained damages. Washouts on

> the railroad and highways, both east and west of Plentywood, isolated the city for nearly 24 hours. The storm began about 1:45 p.m. and the flood occurred during daylight hours rather than at night, otherwise the loss of life might have been greater. During the night of June 30, 1953, fifty-five persons were provided shelter by the local disaster organization. The remainder of the flood victims found shelter with friends and relatives in Plentywood.
>
> The storm was accompanied by heavy hail which cut down a large portion of the vegetation on the Box Elder Creek drainage above the city. When this plant debris was carried into the urban area by floodwater it lodged against fences, hedges and bridges creating temporary dams. This resulted in local rapid rises of floodwaters until the fences and hedges gave way. The water thus released poured into one area after another as the flood progressed downstream. Such conditions caused more severe flooding than the recorded precipitation or the frequency-discharge curves would indicate.

The report also states:

> Unofficial records for the latest flood producing storm, which occurred on June 30, 1953, show a rainfall intensity of 6 inches in 28 minutes at the town of Outlook, 13 miles northwest of Plentywood. The official rainfall for the same storm was reported as 1.71 inches in 24 hours by the U.S. Weather Bureau Station at Plentywood.

As can be seen from the accounts of flooding and damage before Box Elder Creek Dam was constructed, the dam provides flood control to the community of Plentywood.

2.2.2 Reservoir Storage and Spillway Discharge

The reservoir has a surface area of 100 acres and a storage capacity of 1,220 acre-feet at principal spillway crest, elevation 2090.5 feet NGVD. The storage capacity at west emergency spillway crest, elevation 2113.6 feet NGVD is 4,940 acre-feet and at east emergency spillway crest, elevation 2115.1 feet NGVD, capacity is 5,300 acre-feet. Approximately 5,400 acre-feet of surcharge storage is available in the reservoir between the principal spillway crest and the dam crest. The principal spillway discharge is 150 c.f.s. (12 acre-feet per hour); the west emergency spillway discharge is 23,500 c.f.s. (1,940 acre-feet per hour); and the east emergency spillway discharge is 5,950 c.f.s. (490 acre-feet per hour), with the reservoir level at dam crest, elevation 2121.1 feet NGVD.

2.2.3 Estimated Probable Maximum Flood

The probable maximum flood (PMF) is the flood expected from the most severe combination of critical meterologic and hydrologic conditions that are reasonably possible in the region. A preliminary estimate of the PMF was made during this dam safety analysis, and this PMF was routed through the reservoir.

The procedure contained in Hydrometeorological Report No. 51 (Ref. 4) was used to compute the probable maximum precipitation (PMP). This storm produces 17.7 inches in 6 hours and 22.8 inches in 24 hours. The 72-hour precipitation computed by this method is 25.5 inches. Infiltration was assumed to be constant at 0.15 of an inch per hour during the entire flood. Zero base flow was used throughout the flood.

A triangular unit hydrograph for 30-minute rainfall duration was developed for the 20-square-mile drainage basin by procedures outlined in USBR "Design of Small Dams" (Ref. 5). A curvilinear fit of the triangular unit hydrograph was used. The PMP was applied to the unit hydrograph by means of the computer program, HEC-1 (Ref. 6). This preliminary estimate of the PMP produced a flood (PMF) with a peak of 66,600 c.f.s. and a volume of 20,800 acre-feet.

2.2.4 Flood Routing

The PMF was routed through the reservoir by using the computer program HEC-1 (Ref. 6). The routing of the PMF was started with the reservoir water level at the crest of the west emergency spillway to account for conditions that could be caused by antecedent floods. The principal spillway was assumed to be unclogged for the entire flood.

Routing studies indicated that:

- During the full PMF the dam would be overtopped when approximately 33 percent of the flood volume enters the reservoir.

- Routings were made of lesser hypothetical floods than the PMF to determine the magnitude of floods the dam can contain. The hypothetical hydrographs are obtained by applying percentages to the PMF ordinates. A flood with a hydrograph having ordinates corresponding to 49 percent PMF ordinates is just controlled by the project. Larger floods would overtop the dam.

Because of the limited channel capacity of Box Elder Creek through Plentywood, considerable flooding and damage will

occur prior to the overtopping of the dam; combined spillway discharge is near 30,000 c.f.s. However, a failure of the dam would create even more damage.

2.3 GEOTECHNICAL EVALUATION

2.3.1. Dam Embankment

The 60-foot-high, straight-axis homogeneous earthfill embankment is 1,800 feet long and has a crest width of 18 feet. The upstream slope is 1 V on 4 H from the toe up to elevation 2076.0. Above this level the slope is 1 V on 3 H with a 10-foot-wide bench 20 feet above the toe (Plate 10). The downstream slope is 1 V on 2.5 H with a 10-foot-wide bench 30 feet above the toe.

The October 30, 1979 inspection found the embankment material to be a clayey, sandy silt. These embankment materials could quickly erode and rapidly fail when overtopped by floodwaters. The "Watershed Work Plan" (Ref. 3) identified overburden soils as 1 to 5 percent gravel, 20 to 25 percent sand, 24 to 33 percent clay, and 40 to 50 percent silt. The upstream slope (Photo 5) below elevation 2095 is adequately covered with grass and an 18-inch layer of riprap on a 12-inch sand and gravel blanket, and the downstream slope (Photo 6) is covered by grass. No significant erosion, irregularities, slumps, or cracks were found on the dam crest or slopes.

The low-level outlet extends through the embankment founded on about 30 feet of over burden material. The pipe rests on a concrete cradle and is backfilled with compacted earth, probably sandy, clayey silt, as shown on details Plate 4. The condition of the low-level outlet could not be determined because its small size did not allow visual inspection. Cutoff collars were placed approximately 24 feet downstream of the inlet structure.

2.3.2 Foundation Conditions, Seepage, and Drainage

Both abutments consist of glacial till, channel outwash, and terrace gravel overlying stratified sediments of fine silt, sand, and low to highly plastic clay (see section 1.2.3). The foundation materials, as shown on Plate 3, are various layers of silt, clay, and sand for the top 30 to 40 feet, underlain by clay and weathered clay shale. As-built drawings (Plate 10) show that a cutoff trench upstream of dam axis was carried up to 30 feet deep, with side slopes of 1 V on 2 H and a bottom width of 10 feet. Backfill material and method of placement are unknown. The boring logs on Plate 3

indicate that the cutoff trench extended into the clay and clay shale along most of the dam foundation; however, at the east abutment, borings No. 1 and No. 17 show that silty sand layers 10 to 20 feet thick and 15 feet below the cutoff, were left intact beneath the cutoff.

A 60-foot-wide, 3-foot-thick, horizontal sand and gravel interior drainage blanket is incorporated in the downstream slope. The blanket reduces to a 10 foot width, 30 feet up the left abutment and to a 30 foot width, 20 feet up the right abutment. Collector pipes (8-inch-diameter perforated asbestos) along the downstream edge of the blanket and connected to nonperforated exit pipes, carry seepage to the downstream toe along the low-level outlet (Photo 7).

During the inspection, the drain pipes were dry and Mr. Abenroth, SCS representative, mentioned that no flow from the drain had ever been observed. No seepage or erosion from past seepage was observed on the embankment or abutment contacts. Some wet areas were noticed approximately 50 feet downstream from the embankment toe near the left (east) abutment. Seepage was flowing into the old stream channel about 100 feet from the embankment toe downstream of the road (shown in Photo 8). No serious erosion has occurred. The pool elevation during the inspection was 2087.7 feet, 33.4 feet below the top of the dam.

The dam embankment contains no known piezometers.

2.3.3 Stability

Guidelines for dam safety inspections (Ref. 1) recommend that stability analyses be on file for all dams in the high hazard category. Stability analysis with supporting laboratory test data are on file. Based on a review of available information, and the field inspection, it is our judgment that the embankment stability conforms with the recommended guidelines.

2.4 PROJECT OPERATION AND MAINTENANCE

Box Elder Creek Dam is owned and operated by the City of Plentywood. There is no formal operation and maintenance program for the facility. Information on operations and maintenance was obtained through a discussion with Mr. Chester Olson, Plentywood city manager.

2.4.1 Dam

Maintenance of the dam is performed as required. The dam is fairly new and does not require much maintenance. Periodic inspections of the facility are made by the U.S. Soil Conservation Service and the City of Plentywood.

2.4.2 Reservoir

The primary use of the reservoir is flood control. The reservoir level is maintained within a few feet of elevation 2090.5 feet NGVD through the year by the uncontrolled principal spillway. The only regulated releases through the gated low-level outlet are for a small amount of irrigation water for the golf course in Plentywood. Except for these irrigation releases amounting to about 2 feet of storage near the principal spillway level, the low-level outlet gate is normally shut.

2.4.3 Warning System

There is no formal warning plan for use in the event of impending dam failure. Box Elder Dam is on the edge of Plentywood, and many people would be aware of dangerous conditions before the conditions progressed to a point to endanger lives. Many people would be aware of high reservoir levels and any emergency spillway discharge would create additional warning. However, a reliable warning plan is required.

Chapter 3
FINDINGS AND RECOMMENDATIONS

3.1 FINDINGS

Visual inspection of the dam, supplemented by analysis of the project in terms of the recommended guidelines performance standards, resulted in the following findings.

3.1.1 Size, Hazard Classification, and Safety Evaluation

In accordance with inspection guidelines, Box Elder Creek Dam is intermediate in size with a high downstream hazard potential rating. The guidelines recommend that a dam with the above classification be capable of safely handling the PMF. Routing studies indicate that the dam can control a flood having hydrograph ordinates equal to about 50 percent of the PMF hydrograph ordinates. Because the project is incapable of controlling the full PMF without overtopping and causing the dam to fail, Box Elder Creek Dam does not meet inspection guidelines.

3.1.2 Embankment Dam

A visual inspection of the dam revealed neither longitudinal or transverse cracking nor any significant erosion, slumps, or irregularities on the crest of the slopes. The upstream and downstream slopes were adequately protected with grass and riprap. Approximately 100 feet downstream of the embankment near the left (east) abutment, a slight guantity of seepage was observed flowing into the old stream channel. No serious erosion has occurred.

Stability analysis of the dam embankment is on file. Based on a review of available data, the dam embankment stability conforms with the recommended guidelines.

3.1.3 Spillway and Reservoir Capacity

The reservoir has a surface area of 100 acres and a storage of 1,220 acre-feet at principal spillway, elevation 2090.5 feet NGVD. Approximately 3,720 acre-feet of surcharge storage is available in the reservoir between the principal spillway and the west emergency spillway. An additional 1,680 acre-feet of surcharge storage is available between the west emergency spillway at dam crest, elevation 2121.1 feet NGVD. The two emergency spillways have a combined discharge capacity of 29,450 c.f.s with the reservoir at dam crest. The two emergency spillways are unlined and cut in highly erosive soils and would be severely damaged during flood discharges. The west emergency spillway discharges to the valley floor at the toe of the dam. Flood discharges would cause erosion of embankment material which could lead to embankment failure.

3.1.4 Outlet Works

The outlet conduit and the uncontrolled principal spillway riser were not inspected during the site visit. Discharges from the outlet works have not been eroding or backcutting. There is no provision for emergency closure of the principal spillway.

3.1.5 Operation and Maintenance

The City of Plentywood has no formal operations and maintenance plan for Box Elder Creek Dam. Maintenance is performed as required. The reservoir level is maintained within a few feet of elevation 2090.5 feet NGVD through the year by the uncontrolled principal spillway. The only regulated releases through the gated low-level outlet are for a small amount of irrigation water for the golf course in Plentywood. There is no formal warning plan for use in the event of impending dam failure but because of the proximity of the dam to the City, many people would be aware of threatening conditions.

3.2 RECOMMENDATIONS

Because of the storage between normal pool and dam crest, the current project provides a considerable amount of flood protection to Plentywood. The intent of report recommendations is to improve project safety, while preserving this existing flood protection.

The findings suggest that a high priority be given to the following recommendations:

1. Immediately develop, implement, and periodically check an emergency plan for alerting downstream residents in case of impending dam failure.

2. Inspect low-level outlet conduit and riser, and repair as necessary. Modify the principal spillway to provide emergency closure.

3. Conduct more detailed hydrologic and hydraulic routing studies to better determine the downstream hazard and required spillway capacity, and modify the project as studies indicate.

4. Study discharge characteristics and design, and implement modifications to emergency spillway channels to ensure that flows do not erode embankment materials.

5. Conduct periodic inspections of the facility at least at 5-year intervals by engineers with experience in dam design and construction.

REFERENCES

1. U.S. Army Corps of Engineers, Office of the Chief of Engineers Report to the U.S. Congress, National Program of Inspection of Dams, Vol. 1, Appendix D, "Recommended Guidelines for Safety Inspection of Dams," Washington, D.C., Department of the Army, May 1975.

2. Richard D. Eckerlin, U.S. Army Corps of Engineers, Memorandum on Box Elder Creek Dam Geology Inspection, February 1980.

3. U.S. Soil Conservation Service, "Watershed Work Plan, Box Elder Creek Watershed," July 1961.

4. U.S. Department of Commerce, NOAA and U.S. Department of the Army, Corps of Engineers, Hydrometeorological Report No. 51, "Probable Maximum Precipitation Estimates, United States East of the 105th Meridian," Washington, D.C., June 1978.

5. U.S. Bureau of Reclamation, "Design of Small Dams," 2nd Edition, 1974.

6. U.S. Army Corps of Engineers, Hydrologic Engineering Center, HEC-1 Flood Hydrograph Package, Davis, California, January 1973.

Appendix

DEPARTMENT OF NATURAL RESOURCES
AND CONSERVATION
WATER RESOURCES DIVISION

THOMAS L. JUDGE, GOVERNOR

32 SOUTH EWING

STATE OF MONTANA

(406) 449-2872

HELENA, MONTANA 59601

September 30, 1980

Department of the Army
Seattle District, Corps of Engineers
P.O. Box C-3755
Seattle, Wa 98124

Attn: Ralph Morrison

Re: CH2M/Hill Dam Safety Inspection Report on Box Elder Creek Dam (MT-934)

Dear Ralph:

We have reviewed the above referenced final draft report. We concur with the findings and recommendations and find that it satisfies the criteria of the Phase I report.

Minor editorial comments have been discussed with your staff, and we understand these will be incorporated in the final report.

Thank you for this opportunity to review and comment of the final draft report on Box Elder Creek Dam.

Sincerely,

Richard L. Bondy

Richard L. Bondy, P.E.
Chief, Engineering Bureau
(406) 449-2864

RB/AT/lj

United States Department of Agriculture
Soil Conservation Service
P.O. Box 970
Bozeman, MT
59715

September 25, 1980

Sidney Knutson, P.E.
Assistant Chief
Engineering Division
Seattle District
Corps of Engineers
P.O. Box C-3755
Seattle, WA 98124

Dear Mr. Knutson:

Thank you for the opportunity to review the final draft report on Box Elder Creek Dam (MT-934).

Our comments relating to specific report statements are:

Page 10, line 2-6: SCS criteria precludes the use of a gate on a spillway. A gated outlet is not considered a spillway when a full-time attendent is not available. With improper operation, the gate could be closed during a flood event increasing the probability of structure failure over that of a pressurized conduit condition.

We do not agree with the hydrology criteria used to develop the probable maximum flood.

Sincerely,

for Van K Haderlie
State Conservationist

cc:
Homer C. Moore, State Conservation Engineer, SCS, Bozeman
Dave Jones, Environmental Engineer, SCS, Bozeman

CITY OF PLENTYWOOD

PHONE 765-1700
PLENTYWOOD, MONTANA 59254

Plentywood, Montana
December 4, 1980

Department of the Army
Seattle District Corp. of Engineers
P. Box C-3755
Seattle, Washington 98124

Dear Captain Herb,

I am writing this letter pertaining to our telephone conversation on December 3, 1980, in reference to the inspection report of the Box Elder Creek Dam. I wish to have our comments included in the final draft as there are certain areas and contents which we believe are quite hypothetical.

The probable maximum flood which you have estimated is not very probable at all! First of all, you routed the PMF through our reservoir with the water level already being at the crest of the west emergency spillway even before the flood started. It would seem that two floods would be in your thinking to accomplish the emergency spillway being eroded away, as our average level of Box Elder Creek is somewhere between 35-45 feet below your west stage. We would never allow the water level in the dam to raise anywhere near the crest level of the emergency spillway. Each spring, when it starts to thaw, we allow water to be taken out for irrigation purposes--thus fresh water is taken in and the stale water drained out. At any rate, our primary spillway tube would enable us to release a lot of water down Box Elder Creek, thus no crest ever reaching your projected crest height.

Secondly, the rainfall which you hypothesize, 72 hours of non-stop rain resulting in 25.5 inches, is way out of line and ridiculous for this area.

CITY OF PLENTYWOOD

PHONE 765-1700
PLENTYWOOD, MONTANA 59254

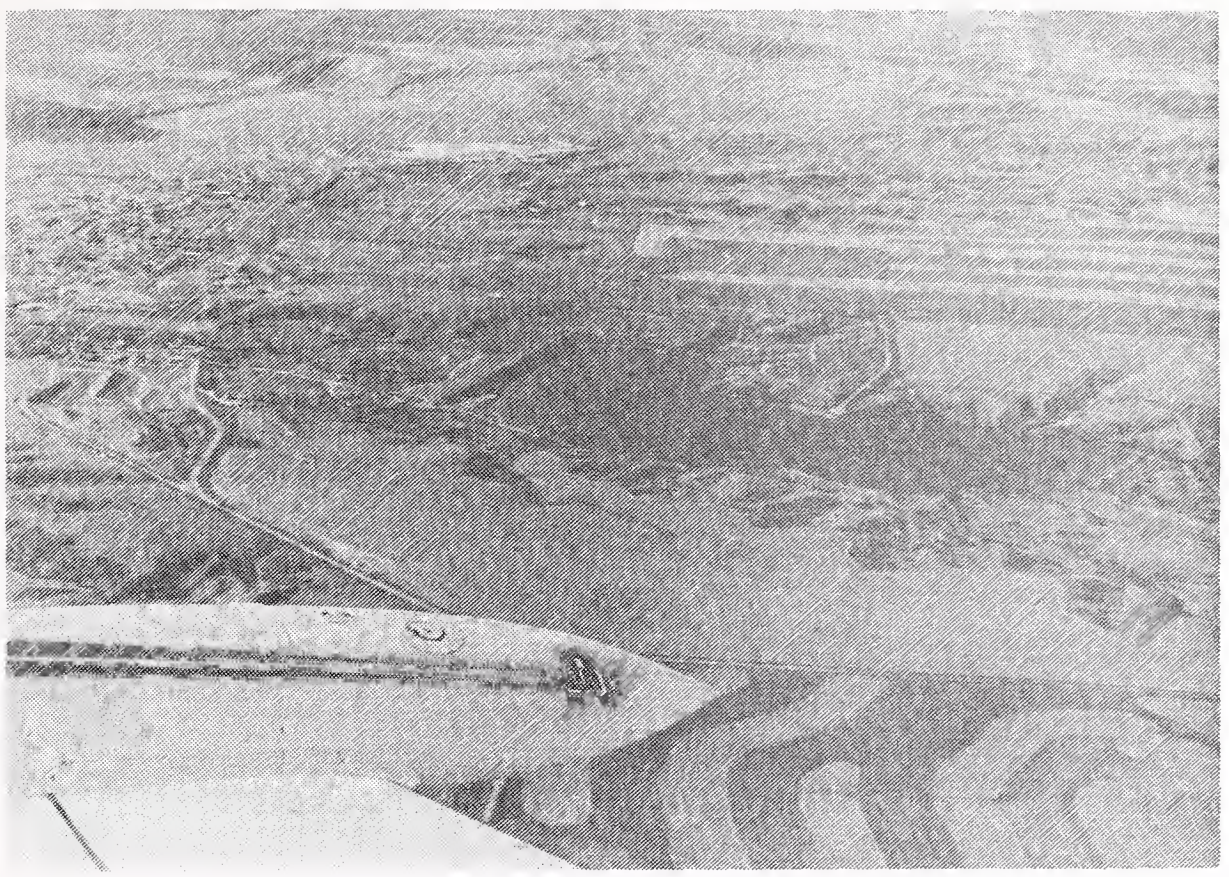
The average total rainfall per year in Sheridan County is only 14.5 inches.

Your recommendations include implementing modifications to our emergency spillway channels to insure that flows do not erode embankment materials. These spillways are presently growing lush grasses upon their surface and are in excellent shape. Due to their size, any additional modifying would result in untold thousands of dollars towards concrete or rock rip-rap work. With your PMF based on such hypothetical happenings, we feel our spillways at present are adequate, if not in excellent shape.

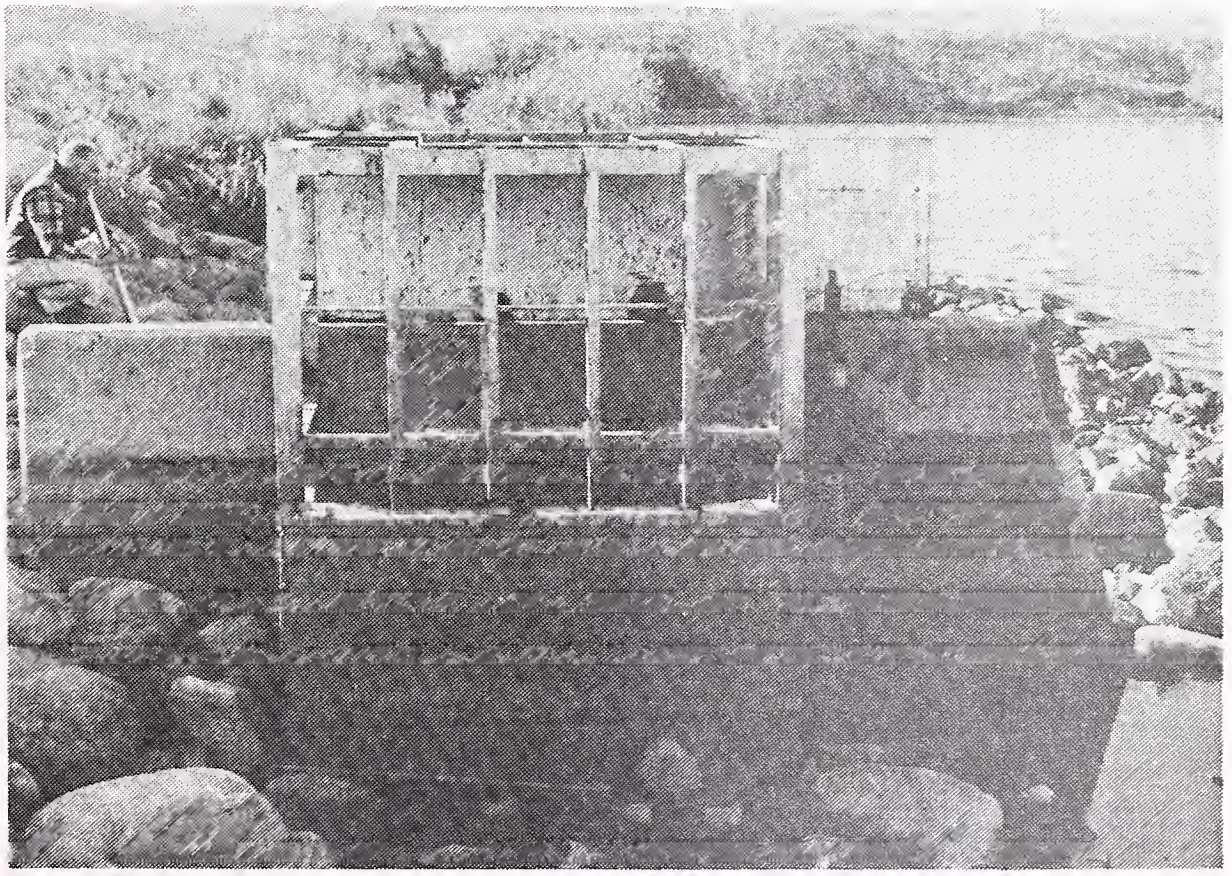
Sincerely,

Bob Marlenee

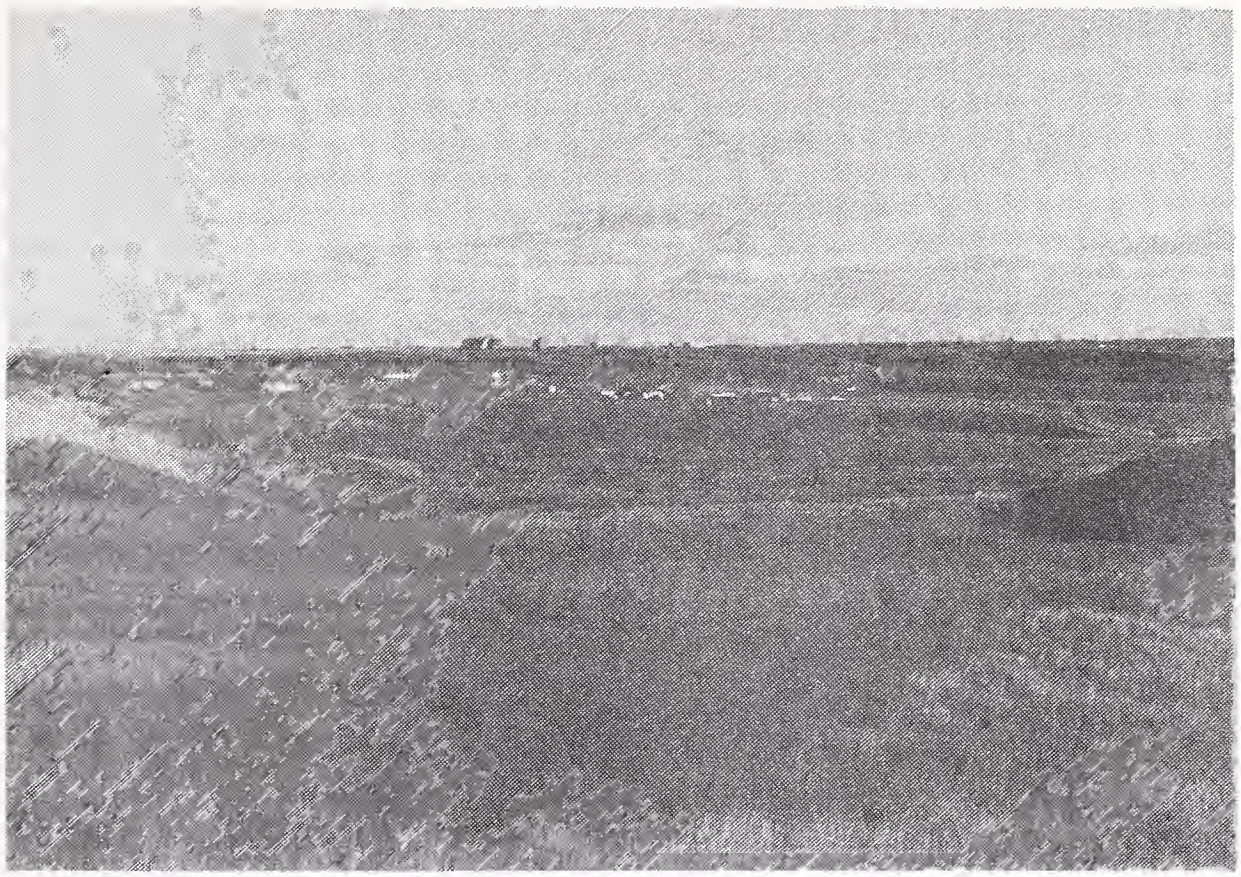
Bob Marlenee
Mayor of Plentywood



(PHOTO 1) DAM AND RESERVOIR



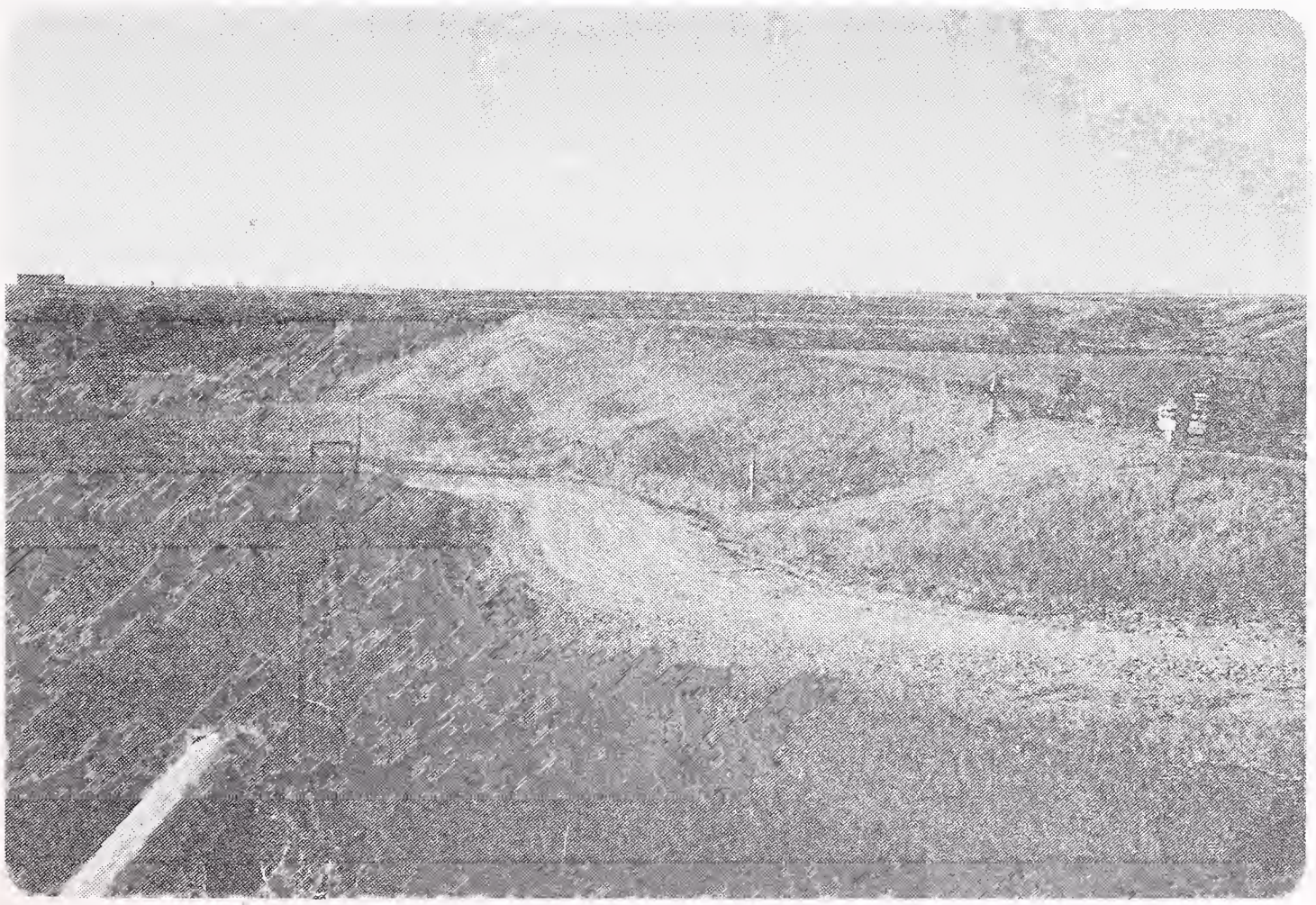
(PHOTO 2) PRINCIPAL SPILLWAY INLET STRUCTURE



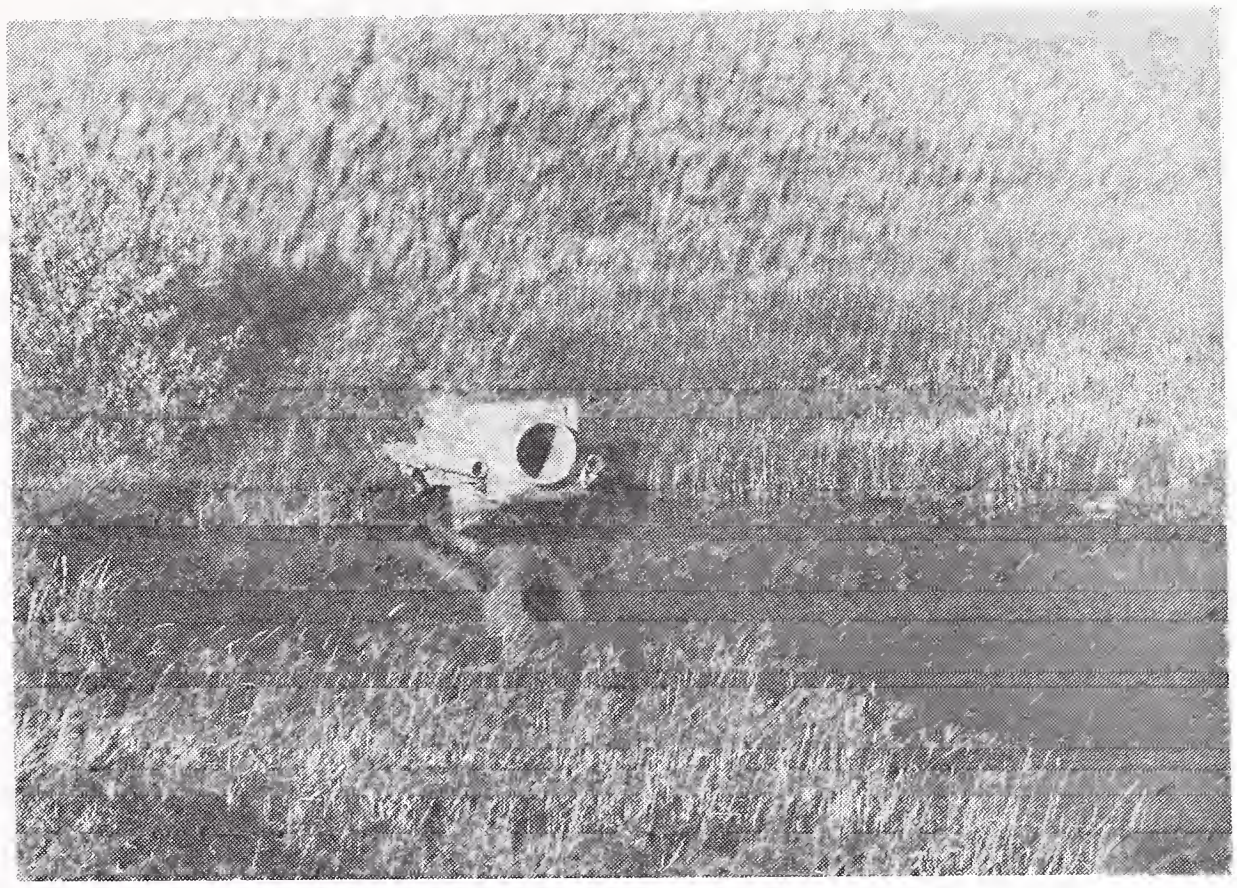
(PHOTO 3) WEST EMERGENCY SPILLWAY - LOOKING DOWNSTREAM

(PHOTO 4) EAST EMERGENCY SPILLWAY - LOOKING UPSTREAM

(PHOTO 5) DAM EMBANKMENT UPSTREAM SLOPE



(PHOTO 6) DAM EMBANKMENT DOWNSTREAM SLOPE



(PHOTO 7) OUTLET WORKS PIPE AND EMBANKMENT DRAINS

(PHOTO 8) DOWNSTREAM OF EMBANKMENT - LOCATING SEEPAGE

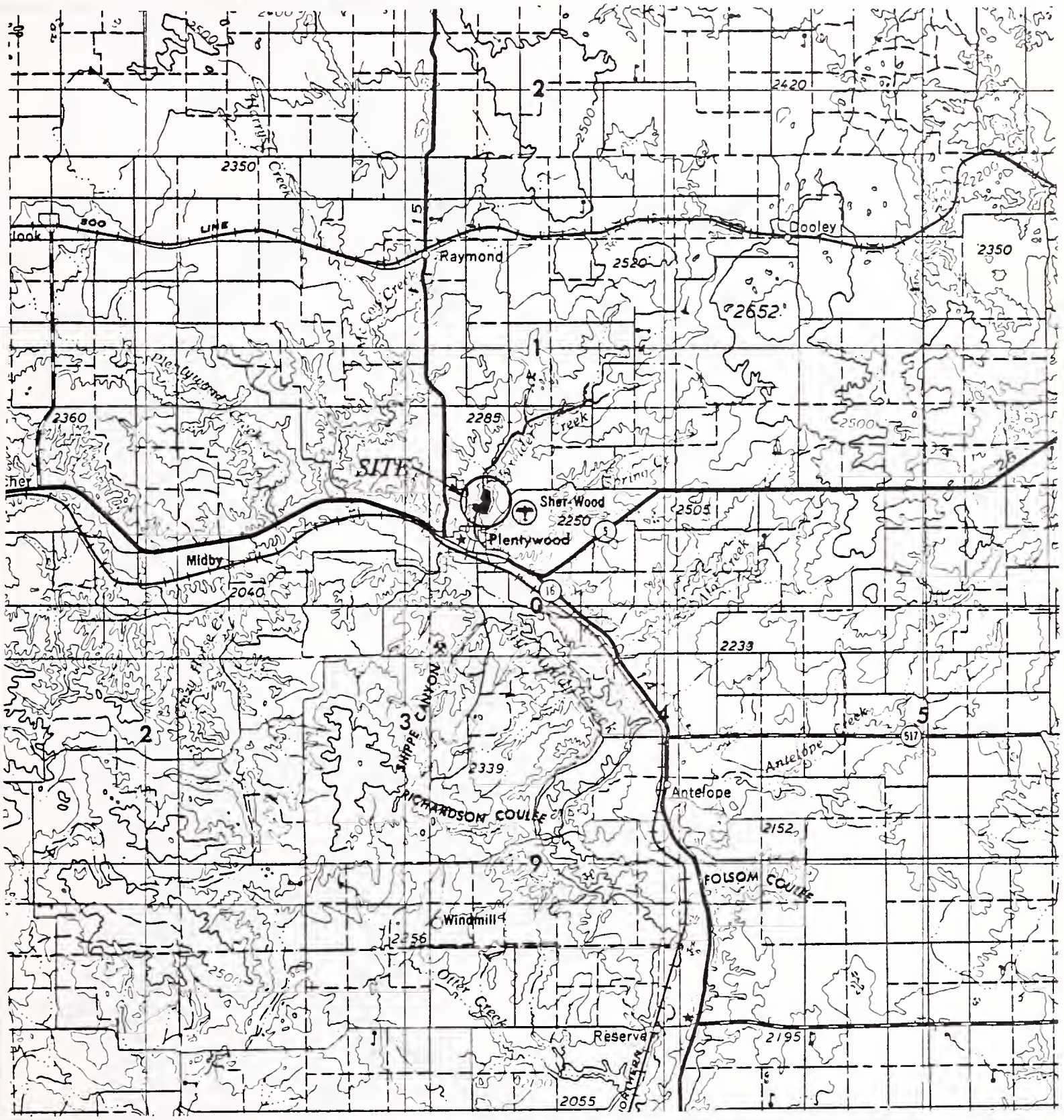
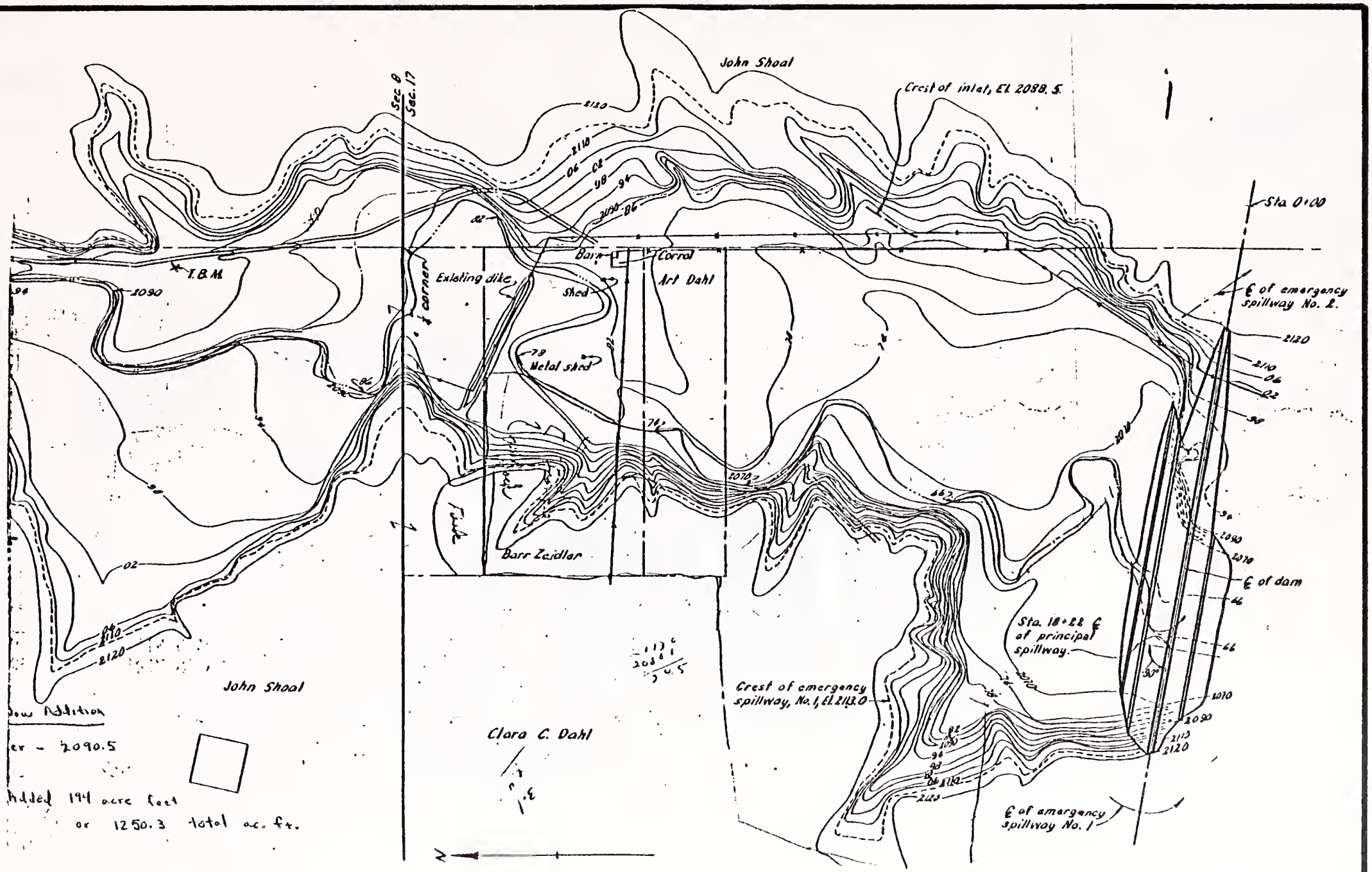


PLATE I
BOX ELDER CREEK DAM
VICINITY MAP

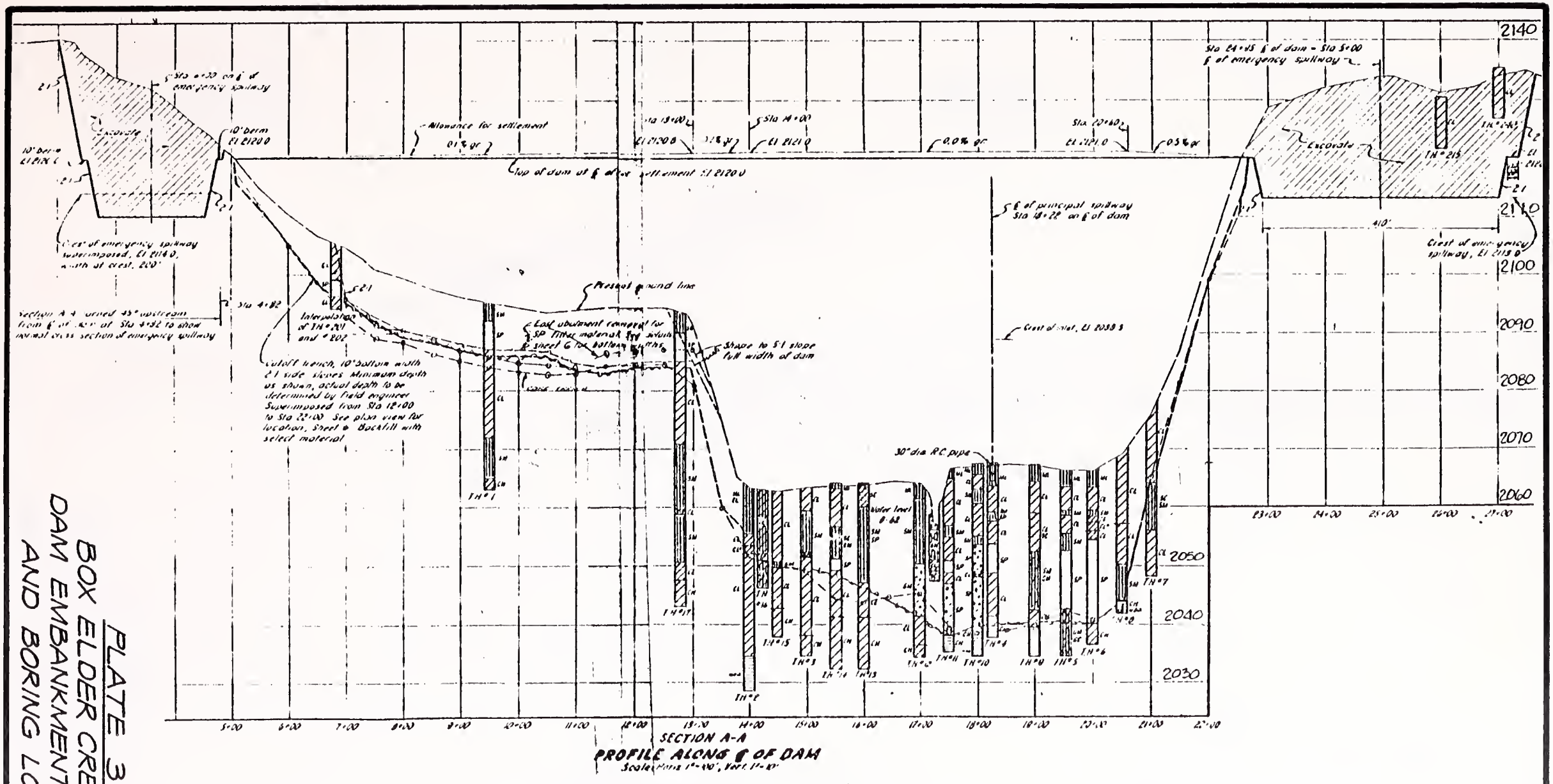
CH2M HILL



SITE PLAN

PLATE 2
BOX ELDER CREEK DAM
SITE PLAN

CH2M HILL



SECTION A-A

PROFILE ALONG ℄ OF DAM

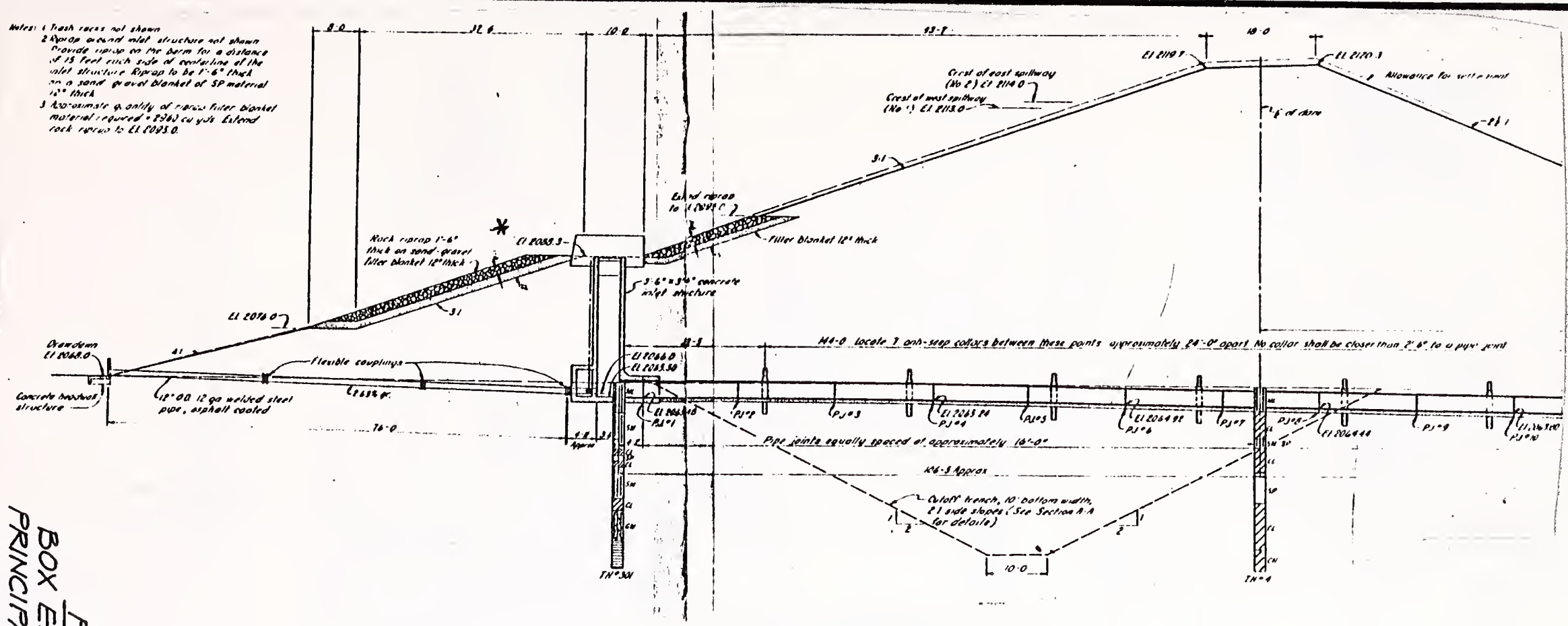
Scale: Horiz 1"=100', Vert 1"=10'

PLATE 3

BOX ELDER CREEK DAM

DAM EMBANKMENT PROFILE AND BORING LOGS

CH2M HILL



* SPILLWAY CREST RAISED 2 FT. IN 1975

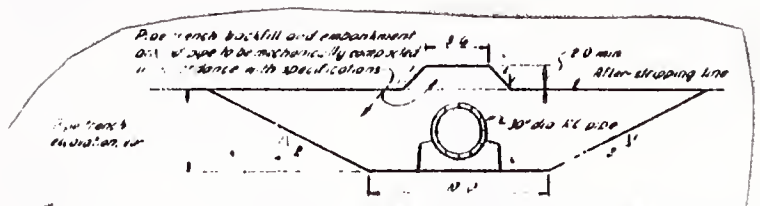


DIAGRAM OF PIPE TRENCH EXCAVATION BACKFILL AND EMBANKMENT

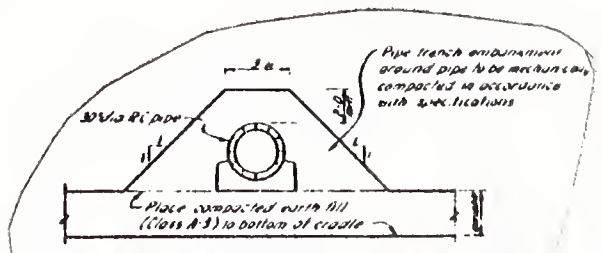


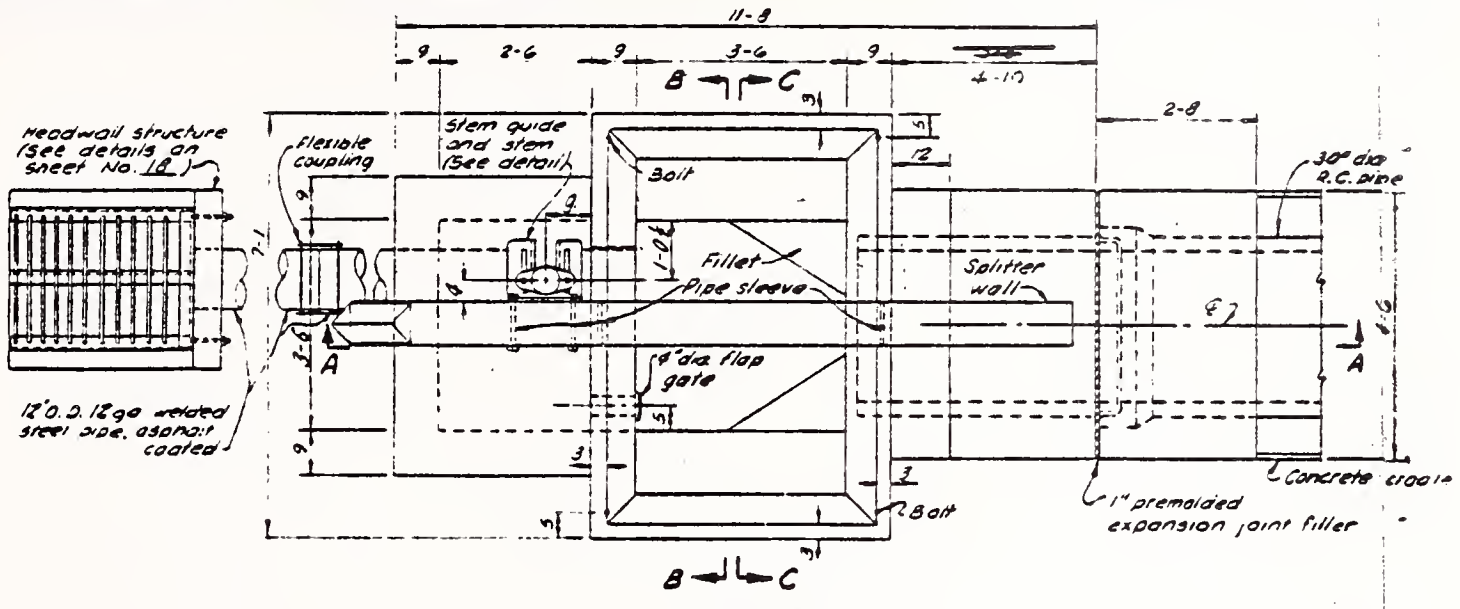
DIAGRAM OF PIPE TRENCH EMBANKMENT IN VICINITY OF CUTOFF TRENCH

Scale 1"=5'-0"

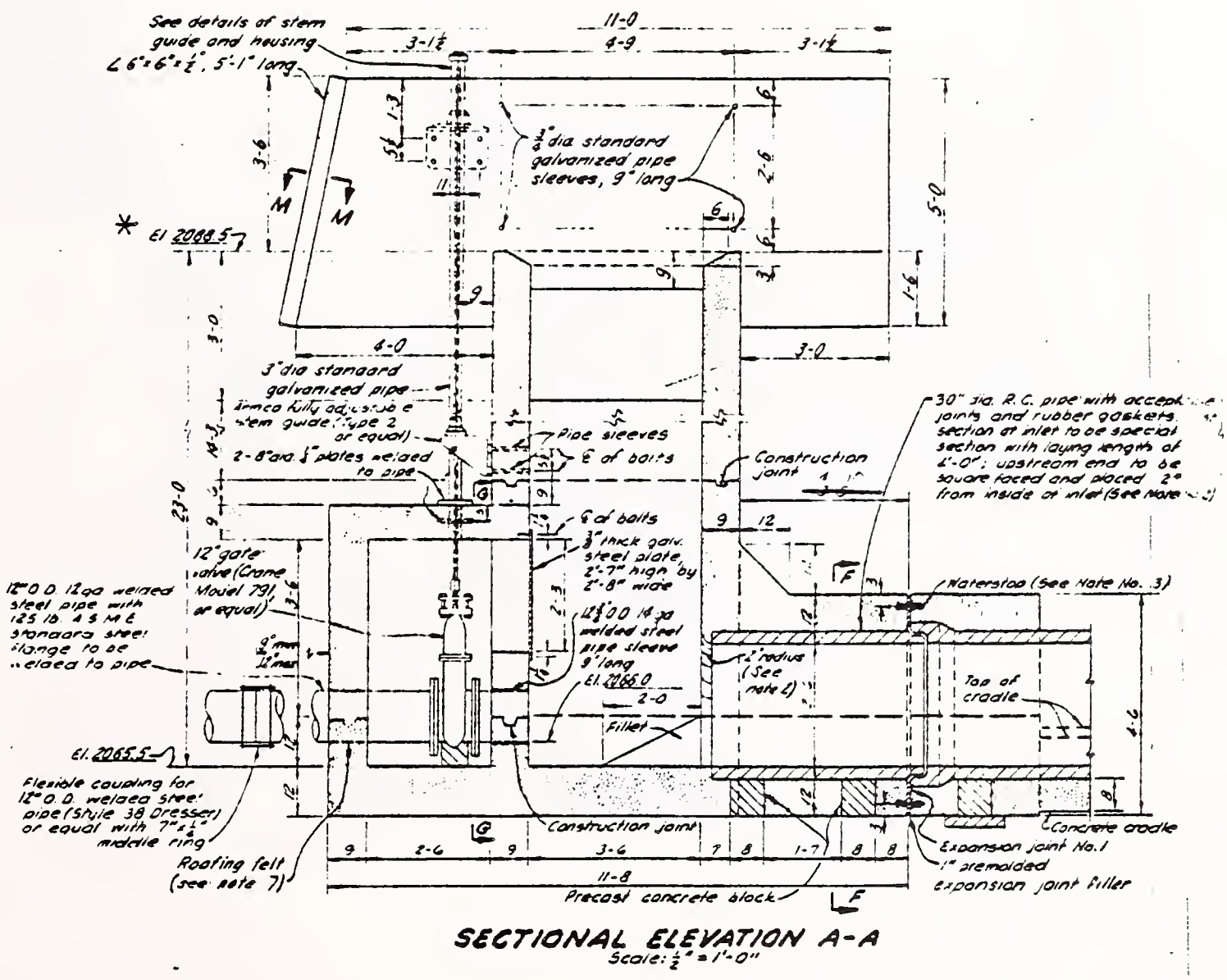
PLATE 4

BOX ELDER CREEK DAM
PRINCIPAL SPILLWAY AND
OUTLET WORKS SECTION

CH2M HILL



PLAN
(Trash rack for inlet not shown)
Scale: $\frac{1}{2}$" = 1'-0"



SECTIONAL ELEVATION A-A
Scale: $\frac{1}{2}$" = 1'-0"

* CREST ELEVATION OF SPILLWAY RAISED 2 FT. IN 1975

PLATE 5
BOX ELDER CREEK DAM
PRINCIPAL SPILLWAY INLET
PLAN AND SECTION

CH2M HILL

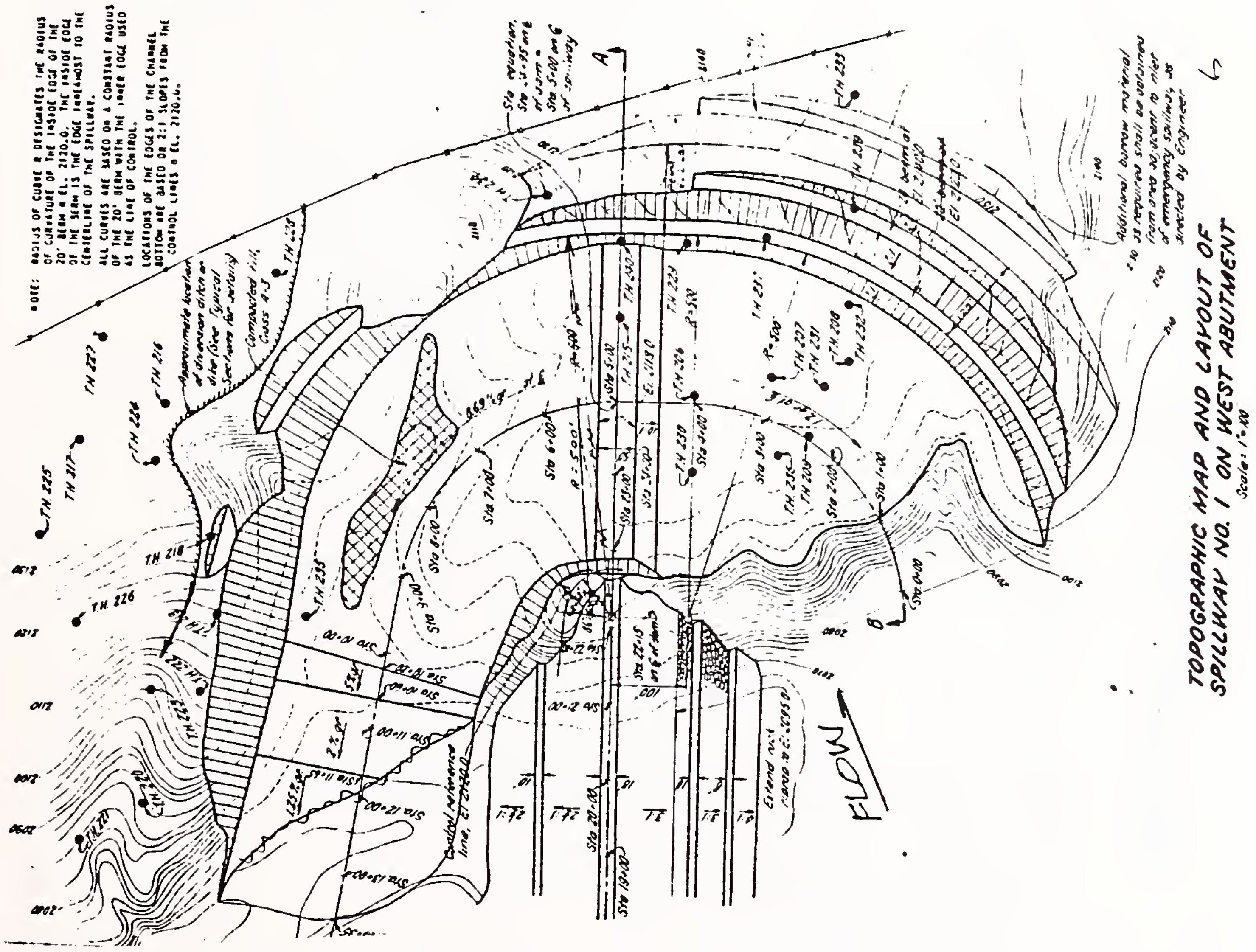


PLATE 6

BOX ELDER CREEK DAM
WEST EMERGENCY
SPILLWAY PLAN

CH2M HILL

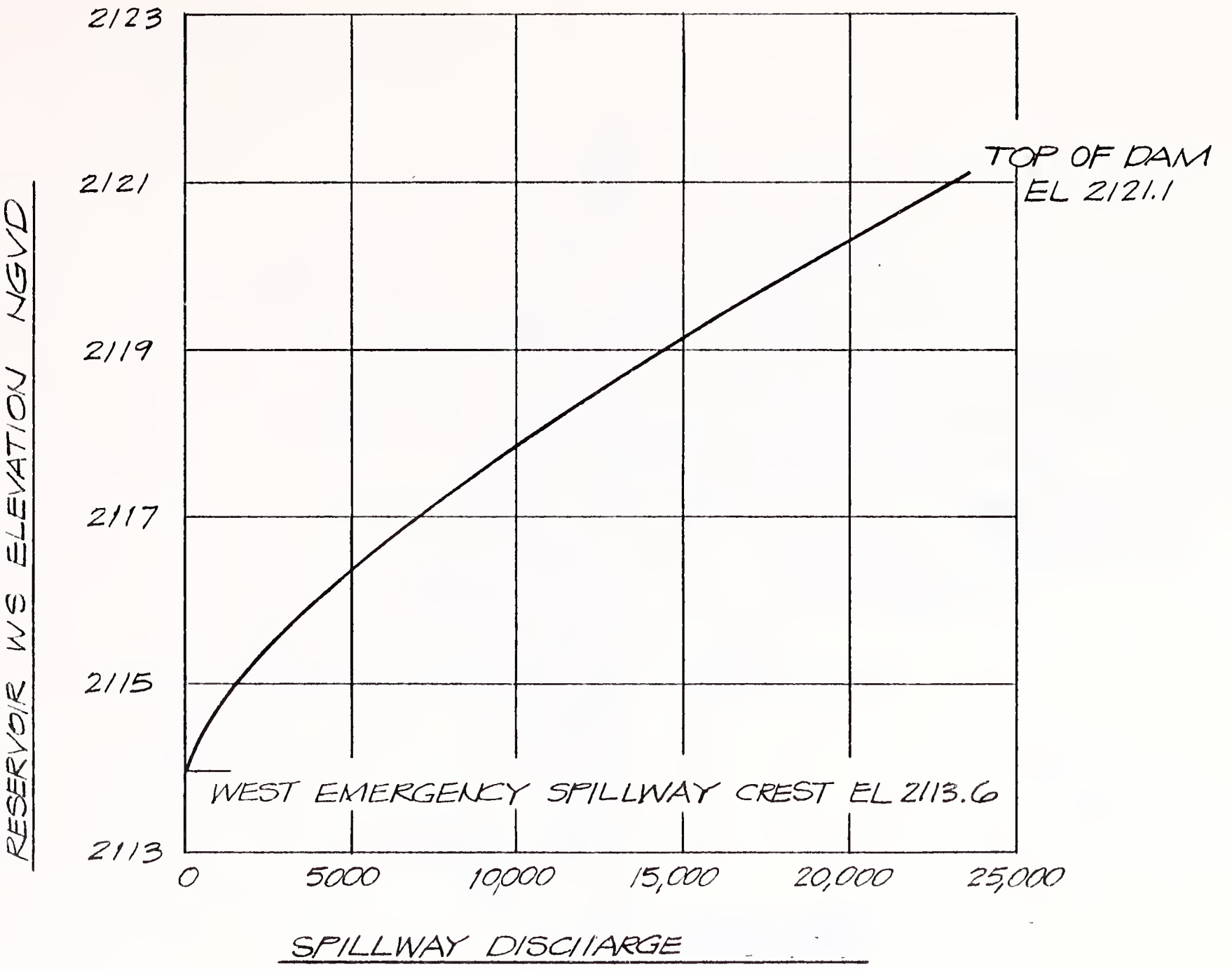


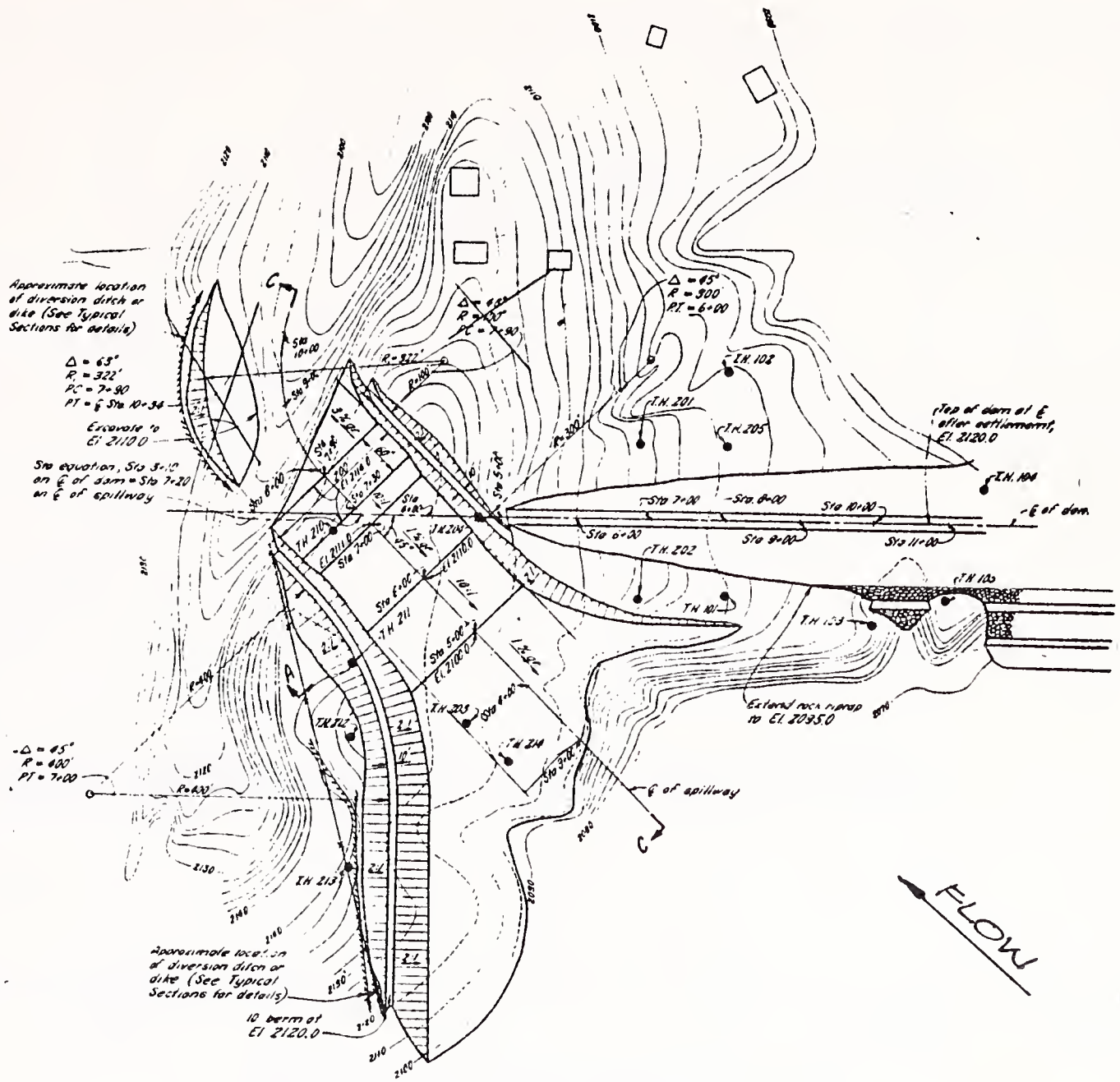
PLATE 7

BOX ELDER CREEK DAM

WEST EMERGENCY

SPILLWAY RATING CURVE

CH2M HILL



TOPOGRAPHIC MAP AND LAYOUT OF SPILLWAY NO. 2 ON EAST ABUTMENT

Scale: 1" = 100'

PLATE 8

BOX ELDER CREEK DAM

EAST EMERGENCY SPILLWAY PLAN

CH2M HILL

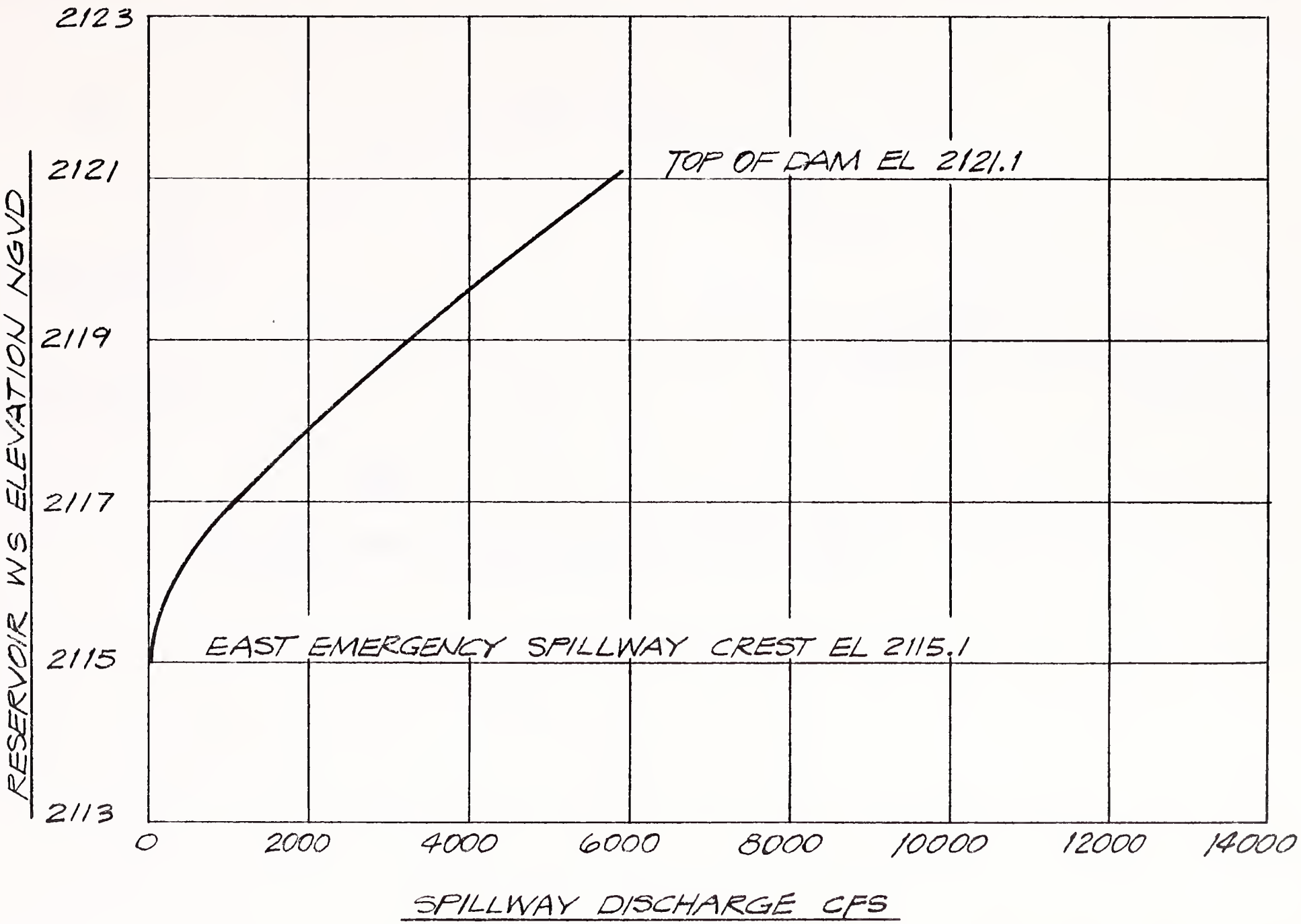
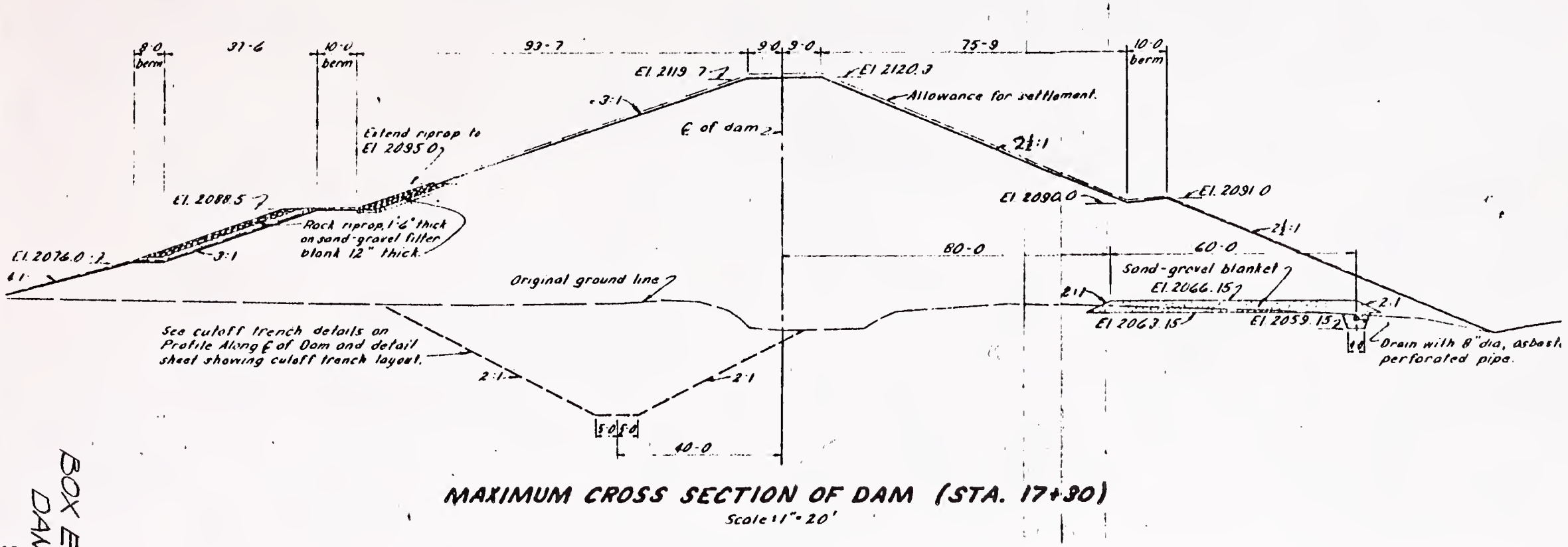


PLATE 9
BOX ELDER CREEK DAM
EAST EMERGENCY
SPILLWAY RATING CURVE

CH2M HILL



MAXIMUM CROSS SECTION OF DAM (STA. 17+30)

Scale 1"=20'

PLATE 10

BOX ELDER CREEK DAM

DAM EMBANKMENT SECTION

CH2M HILL